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(54) Title: METHOD AND APPARATUS FOR DETERMINING CHARACTERISTICS OF COMPONENTS OF A COMMUNICATION CHANNEL UNDER LOAD
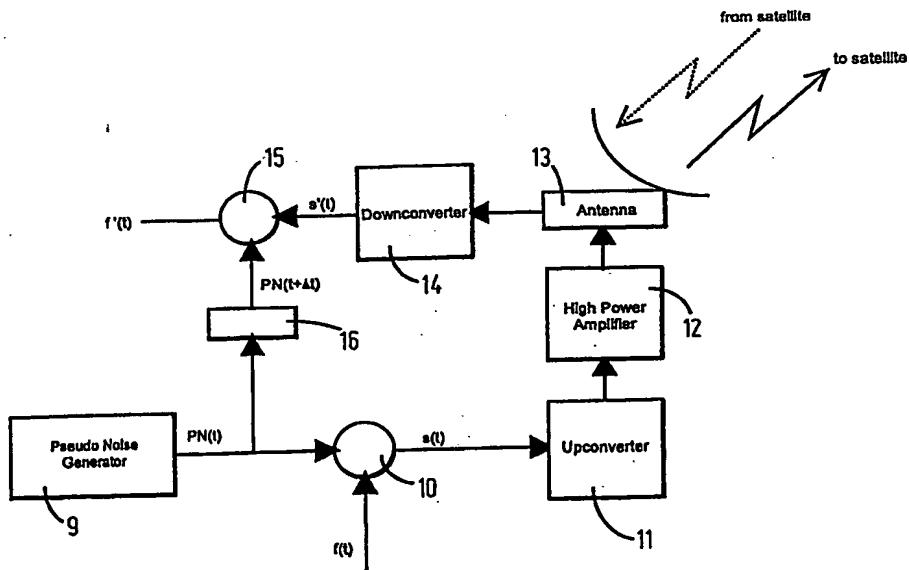
(57) Abstract

For determining characteristics of components of a communication channel, for example of a transponder in a communication satellite, a clean carrier signal f(t) is modulated with a pseudo noise signal PN(t) and transmitted through the communication channel at a level below the level of a payload signal which is transmitted via the communication channel simultaneously. The received signal s'(t) is correlated with same pseudo noise signal PN(t) to obtain a recovered carrier signal f'(t). Both the clean carrier signal f(t) and the recovered carrier signal f'(t) can be used to determine the desired characteristics. Since the PN modulated clean carrier signal s(t) is transmitted at a low level, it is possible to perform measurements without switching off the payload signal.

Method and apparatus for determining characteristics of
components of a communication channel under load

This invention relates to a method and an apparatus for
determining characteristics of components of a
communication channel, especially a transponder in a
communication satellite under load.

The characteristics of a communication channel may change
during the lifetime of the equipment used. Various tests
may be performed not only at the beginning of but also
repeatedly during the lifetime to verify that the
communication channel meets predetermined specifications.
Usually, these tests are performed without normal traffic,
i.e. without the communication channel being used for
transmission of a communication signal. This scenario will
be explained in the following in greater detail with
reference to communication satellites but without limiting
the invention disclosed further below to only this
application although the invention is specifically
applicable in this field.

In a communication satellite, a communication channel is
set up by a transponder of the satellite comprising several
components like a receiving antenna, an input
demultiplexer, a power amplifier, an output multiplexer,
and a transmitting antenna. Transponder characteristics,
such as amplitude response and group delay, are measured
not only at the beginning of life of the spacecraft on the
ground and, after launch, in orbit but also during the
lifetime. These measurements are conventionally carried out
without normal traffic on the transponder, i.e. without a

payload signal being transmitted to and being re-
transmitted by the transponder.

The necessity of switching off the payload signal during
5   tests represents a considerable drawback not only for the
user of the transponder, since communication is
interrupted, but also for the operator of the satellite
since the tests have to be performed in an expedited manner
to keep the interruption as short as possible. In some
10 cases it is impossible to interrupt communications via the
communication channel so that the components of these
channels cannot be tested after having enters into
operation.

15 It is an object of the present invention to provide a
method and an apparatus for determining characteristics of
components of a communication channel, especially a
transponder of a satellite, without the necessity to
interrupt traffic via the communication channel.
20

This object and other objects are achieved by a method for
determining characteristics of components of a
communication channel through which a payload signal is
transmitted at a predetermined level, comprising:
25 generating a first pseudo noise signal $PN(t)$; modulating a
clean carrier signal $f(t)$ with said first pseudo noise
signal $PN(t)$ to generate a PN modulated clean carrier
signal $s(t)$; transmitting said PN modulated clean carrier
signal $s(t)$ simultaneously with said payload signal through
30 said communication channel at a level below the level of
said payload signal; receiving a receive signal $s'(t)$
corresponding to said PN modulated clean carrier signal
$s(t)$ after having traveled through said communication
channel; correlating said receive signal $s'(t)$ with said
35 first pseudo noise signal $PN(t)$ to generate a recovered
carrier signal $f'(t)$; and determining characteristics of
components of the communication channel on the basis of a

comparison of said clean carrier signal f(t) and said recovered carrier signal f'(t).

Advantageously, the level of said PN modulated clean carrier signal s(t) is at least 15 dB, preferably 25 dB or more below the level of said payload signal.

In a further embodiment, said first pseudo noise signal PN(t) is a binary pseudo noise sequence, which is preferably generated by means of a feed back shift register.

A chiprate of said first pseudo noise signal PN(t) is less than 5 MChip/s and preferably less than or equal to 2,5 MChip/s.

In a further embodiment, said correlating of said receive signal s'(t) and said first pseudo noise signal PN(t) is achieved by delaying said first pseudo noise signal PN(t) and multiplying the delayed first pseudo noise signal PN(t) and said receive signal s'(t).

To generate a reference, the method according to the invention further comprises: generating a second pseudo noise signal $PN_R(t)$; modulating a reference carrier signal $f_R(t)$ with said second pseudo noise signal $PN_R(t)$ to generate a PN modulated reference carrier signal $s_R(t)$; transmitting said PN modulated reference carrier signal $s_R(t)$ simultaneously with said payload signal through said communication channel at a level below the level of said payload signal; receiving a reference receive signal $s_R'(t)$ corresponding to said PN modulated reference carrier signal $s_R(t)$ after having traveled through said communication channel; correlating said reference receive signal $s_R'(t)$ with said second pseudo noise signal $PN_R(t)$ to generate a recovered reference carrier signal $f_R'(t)$; and determining characteristics of components of the communication channel

also on the basis of a comparison of said reference carrier signal $f_R(t)$ and said recovered carrier signal $f_R'(t)$.

Advantageously, the level of said PN modulated reference
5   carrier signal $s_R(t)$ is at least 15 dB, preferably 25 dB or more below the level of said payload signal.

In a further embodiment, said second pseudo noise signal $PN(t)$ is a binary pseudo noise sequence which is preferably
10   generated by means of a feed back shift register.

In a further embodiment, said correlating of said reference receive signal $s_R'(t)$ and said second pseudo noise signal $PN_R(t)$ is achieved by delaying said second pseudo noise
15   signal $PN_R(t)$ and multiplying the delayed second pseudo noise signal $PN_R(t)$ and said reference receive signal $s_R'(t)$.

The method of the invention as characterized above is
20   especially applicable when said communication channel is a transponder of a communication satellite. Said PN modulated reference signal $s_R(t)$ may be transmitted through the same transponder of the satellite, but then said second pseudo noise signal $PN_R(t)$ must not correlated with said pseudo
25   noise signal $PN(t)$. Said PN modulated reference signal $s_R(t)$ can also be transmitted through a different transponder of the satellite.

The characteristics of said communication channel may be
30   group delay and amplitude response.

The above objects and other objects are also achieved by an apparatus for determining characteristics of components of a communication channel through which a payload signal
35   is transmitted at a predetermined level, comprising first pseudo noise signal generating means for generating a pseudo noise signal $PN(t)$; first modulating means for

modulating a clean carrier signal f(t) with said first
pseudo noise signal PN(t) to generate a PN modulated clean
carrier signal s(t); transmitting means for transmitting
said PN modulated clean carrier signal s(t) simultaneously
5   with said payload signal through said communication channel
at a level below the level of said payload signal;
receiving means for receiving a receive signal s'(t)
corresponding to said PN modulated clean carrier signal
s(t) after having traveled through said communication
10 channel; and first correlating means for correlating said
receive signal s'(t) with said pseudo noise signal PN(t) to
generate a recovered carrier signal f'(t).

Advantageously, the level of said PN modulated clean
15 carrier signal s(t) is at least 15 dB, preferably 25 dB or
more below the level of said payload signal.

In a further embodiment, said first pseudo noise signal
generating means is a feed back shift register.
20
A chiprate of said first pseudo noise signal PN(t) is less
than 5 MChip/s preferably less than or equal to 2,5
MChip/s.

25 In a further embodiment, the above apparatus comprises
first delaying means for delaying said first pseudo noise
signal PN(t).

To obtain a reference, the above apparatus further
30 comprises second pseudo noise generating means for
generating a second pseudo noise signal $PN_R(t)$; second
modulating means for modulating a reference carrier signal
$f_R(t)$ with said second pseudo noise signal $PN_R(t)$ to
generate a PN modulated reference carrier signal $s_R(t)$;
35 transmitting means for transmitting said PN modulated
reference carrier signal $s_R(t)$ simultaneously with said
payload signal through said communication channel at a

level below the level of said payload signal; receiving means for receiving a reference receive signal $s_R'(t)$ corresponding to said PN modulated reference carrier signal $s_R(t)$ after having traveled through said communication

5 channel; and second correlating means for correlating said reference receive signal $s_R'(t)$ with said second pseudo noise signal $PN_R(t)$ to generate a recovered reference carrier signal $f_R'(t)$.

10 Advantageously, the level of said PN modulated reference carrier signal $s(t)$ is at least 15 dB, preferably 25 dB or more below the level of said payload signal.

In a further embodiment, said second pseudo noise signal

15 generating means is a feed back shift register.

In a further embodiment, the above apparatus further comprises second delaying means for delaying said second pseudo noise signal $PN_R(t)$.

20

In summary, for determining characteristics of components of a communication channel, for example of a transponder in a communication satellite, a clean carrier signal $f(t)$ is modulated with a pseudo noise signal $PN(t)$ and transmitted

25 through the communication channel at a level below the level of a payload signal which is transmitted via the communication channel simultaneously. The received signal $s'(t)$ is correlated with the same pseudo noise signal $PN(t)$ to obtain a recovered carrier signal $f'(t)$. The clean

30 carrier signal $f(t)$ and the recovered carrier signal $f'(t)$ are used together to determine the desired characteristics. Since the PN modulated clean carrier signal $s(t)$ is transmitted at a low level, it is possible to perform measurements without switching off the payload signal.

35

The most important advantage of the method and the apparatus according to the invention is of course that the

payload signal does not have to be switched off for performing the measurements. This limits considerably the downtime required for maintenance and verification of the communication channel, and thus increases availability of
5   services.

Another very important advantage is the fact that with this method and apparatus, it is possible to measure characteristics of components of the communication channel
10   under realistic conditions. For example, in a satellite transponder the IMUX and OMUX filters are waveguide filters and the characteristics of these filters are changing with the temperature. Normally, the filters are not uniformly heated during operation but are heated depending on the
15   payload signal. When the payload signal is switched off the temperature distribution changes compared to normal operation even if the test signals provide a certain power for heating the filters. Thus, with conventional methods characteristics cannot be determined under conditions
20   present in the communication channel under load. In addition, in the proposed method the spectral power density of the measurement signal is considerably lower than the spectral power density of the payload signal, so that it is possible to characterise the behaviour of the
25   communications channel under the most realistic circumstances.

A further advantage of the invention is that in the case of a satellite communication channel the conversion frequency
30   of the uplink/downlink can be measured without interruption of the payload signal and simultaneously with the other measurements.

In the following an embodiment of the invention will be
35   described in greater detail and with reference to the drawings.

Fig. 1   shows a schematic diagram of a transponder of a
         communication satellite;

Fig. 2   shows a schematic diagram of a first embodiment
         of an apparatus according to the invention;

Fig. 3a and 3b show diagrams representing measurement
             result;

Fig. 4   shows a schematic diagram of a second embodiment
         of an apparatus according to the invention.

For the purpose of describing an embodiment of the
invention, Fig. 1 shows the components of a transponder in
a communication satellite as an example for a communication
channel.

A transponder of a communication satellite comprises a
receiving antenna 1 for receiving an uplink signal send
from a ground station (not shown). An output signal of said
receiving antenna 1 is fed to an input demultiplexer (IMUX)
3 after frequency conversion in frequency converter 2. Said
input demultiplexer 3 comprises several first filters 4-1
to 4-n for separating individual signals within the signal
from the antenna. Typically, one filter is provided for
each signal to be separated from the other signals received
via said receiving antenna 1 and corresponds to a
communication channel. The n output signals of said input
demultiplexer 3 are fed to a corresponding number of high
power amplifiers 5-1 to 5-n in each of which a traveling
wave tube (TWT) is employed for amplifying the output
signals of said input demultiplexer 3. As each of said high
power amplifiers is normally operated in its saturation
point, multiple signals would create intermodulation
products and distortion of the signals. The amplifier
output signals are passed through second filters 6-1 to 6-n
which are part of an output multiplexer (OMUX) 7 combining

the n amplifier output signals. The output signal of said
output multiplexer 7 is fed to a transmitting antenna 8 for
being transmitted to the desired area on the ground.

5   Since the filters provided in the input demultiplexer
       (IMUX) 3 and the output multiplexer (OMUX) 7 have a strong
       influence on the performance of the transponder, the method
       according to the invention will be explained in following
       with respect to measuring two specific characteristics,
10   namely amplitude response and group delay, of these
       components of the transponder communication channels, the
       method of the invention being especially suitable for this
       application. However, the same or other characteristics of
       other components of the communication channel can be
15   determined by means of the method and the apparatus
       according to the invention.

       According to the invention, in a ground station as shown in
       Fig. 2, a pseudo noise signal PN(t) is generated by means
20   of a pseudo noise signal generator 9, for example, a feed
       back shift register or a memory device in which a sequence
       of values of a pseudo noise signal is stored. The pseudo
       noise signal PN(t) has a very sharp autocorrelation
       function at zero delay. This allows to determine the time
25   delay between the locally generated pseudo noise signal
       PN(t) and a received signal which is delayed due to the
       propagation time. A clean carrier signal f(t) having a
       variable frequency, which is changed as explained further
       below, is modulated with said pseudo noise signal PN(t) by
30   means of a first multiplier 10 to form a PN modulated clean
       carrier signal s(t) = PN(t) x f(t). The chiprate of the
       pseudo noise signal PN(t), which determines the bandwidth
       of this signal, is chosen such the bandwidth of the PN
       modulated clean carrier signal s(t) is narrow in comparison
35   with the expected peaks in group delay of the communication
       channel. Typically, the chiprate of the pseudo noise signal
       may be chosen less than 5 MChip/s.

The PN modulated clean carrier signal s(t) is fed to an
upconverter 11 and via a high power amplifier 12 to an
antenna 13 which transmits the PN modulated clean carrier

5   signal s(t) to the transponder of the communication
satellite under test. However, from the viewpoint of a user
transmitting a payload signal to the satellite, the
transponder remains usable during the test and can be
continuously supplied with a payload signal.

10

According to the invention, the level of the transmitted PN
modulated clean carrier signal s(t) is sufficiently below
the level of the payload signal, for example about 15 to 25
dB or more, such that the payload signal is not notably

15   deteriorated. For this reason, the PN modulated clean
carrier signal s(t) can be transmitted while the
communication channel is in use, i.e. simultaneously with a
payload signal being transmitted to the transponder of the
satellite from the same or from another ground station.

20

The frequency of the clean carrier signal f(t) is changed
such that it sweeps from the lowest to the highest
frequency of the pass band of the filters in the satellite
transponder, or any other component of a general

25   communication channel under test. The PN modulated clean
carrier signal s(t) has a narrow bandwidth due to the
pseudo noise signal PN(t) such that amplitude response and
group delay of the communication channel can be determined
at selected discrete frequencies, as will be described in

30   the following.

In the embodiment, antenna 13 is also used to receive the
signal re-transmitted by the transponder of the satellite,
in other words the signal which has traveled through the

35   communication channel. The output signal of antenna 13 is
passed through a downconverter 14 to obtain a receive
signal s'(t) which is fed to a second multiplier 15

receiving also the same but delayed pseudo noise signal
PN(t). The delay is generated by delaying means 16 which
are set such that the output of the second multiplier 15
becomes maximal. Thereby, the receive signal s'(t) is

5   multiplied, in other words correlated with the very same
pseudo noise signal PN(t) which has been used for
generating the PN modulated clean carrier signal s(t) and a
recovered carrier signal f'(t) is obtained which is only
delayed and attenuated in comparison with the clean carrier

10   signal f(t). Thus, the amplitude response, which
corresponds to the attenuation of the recovered carrier
signal f'(t), and the group delay, which corresponds to the
delay of the recovered carrier signal f'(t), of the
transponder of the satellite, as an example of a general

15   communication channel, can easily be determined. The
runtime of a narrowband signal at its center frequency
corresponds to the group delay of the filters if the phase
can be linearly approximated in the signal bandwidth. The
chiprate of the PN signal is determined accordingly.

20
As far as communication satellites are concerned, it is
sufficient to determine the amplitude response and group
delay over the pass band of a transponder only relative to
the amplitude response and group delay at the center

25   frequency of the pass band. Therefore, it is sufficient to
delay the pseudo noise signal PN(t) such that the amplitude
of the recovered carrier signal f'(t) becomes maximal and
to subtract the amplitude and the delay at the center
frequency from the amplitude and the delay at any other

30   frequency in the pass band, respectively.

Fig. 3a and 3b show typical measurement result for
amplitude response (Fig. 3a) and group delay (Fig.3b) as
obtained by the method according to the invention.

35
In the case of a satellite communication channel, i.e. a
transponder, it should be noted that, during measurements,

due to the movements of the satellite the distance to the
satellite can change. Also, during measurements, due to
atmospherical effects the attenuation of the path loss
between the ground station and the satellite can change.

5   Since in the above embodiment the amplitude response and
the group delay is determined by subtracting the amplitude
response and the group delay at the center frequency from
the respective values at other discrete frequencies, an
error might occur due to the before mentioned satellite

10   movements and atmospherical effects or other influences.

As shown in Fig. 4, an reference signal $s_R(t)$ can be used to
compensate the before mentioned measurement error. In Fig.
4 the same reference signs are used for those parts already

15   described above and reference is made to the above
description of these parts. The reference signal $s_R(t)$ is
generated by means of a third multiplier 18 which receives
a second pseudo noise signal $PN_R(t)$, which is not
correlated with the first pseudo noise signal $PN(t)$ and

20   which is generated by a second pseudo noise generator 17,
and a reference carrier signal $f_R(t)$ which may be located
at a fixed frequency somewhere within the pass band of the
same transponder or in the pass band of another transponder
on the same satellite having a different center frequency.

25   Like in the above embodiment, a PN modulated reference
carrier signal $s_R(t)$ is transmitted to the satellite and
the reference receive signal $s_R'(t)$ is multiplied with the
second pseudo noise signal $PN_R(T)$ to obtain the recovered
reference signal $f_R'(t)$. While the measurement signal is

30   swept in frequency over the transponder pass band, the
frequency of the reference carrier signal $f_R(t)$ remains at
a fixed frequency. Therefore, a corrected amplitude
response and group delay of the communications channel can
be obtained by subtracting the values of the reference

35   signal from the values of the measurement signals at the
respective time.

A variation of the described measuring the group delay consists of measuring the phase of the reconstructed carrier of the PN modulated signal at a specified frequency very close to the first frequency, it is possible to
5   approximate the group delay at the frequency located in the middle of both measurement frequencies by calculating the phase difference and dividing by the frequency difference.

Only pseudo noise signals have been discussed above because
10   these signals can be generated comparatively easily. However, true noise signals can be used in the method and the apparatus according to the invention. Properties of true and pseudo noise signals are well known to those skilled in the art and are described, for example in
15   Bernard Sklar, "Digital Communications - Fundamentals and Applications", Prentice Hall, 1988.

Claims

1. Method for determining characteristics of components
    of a communication channel through which a payload
    signal is transmitted at a predetermined level,
    comprising:
    -   generating a first pseudo noise signal PN(t);
    -   modulating a clean carrier signal f(t) with said
    first pseudo noise signal PN(t) to generate a PN
    modulated clean carrier signal s(t);
    -   transmitting said PN modulated clean carrier
    signal s(t) simultaneously with said payload signal
    through said communication channel at a level below
    the level of said payload signal;
    -   receiving a receive signal s'(t) corresponding to
    said PN modulated clean carrier signal s(t) after
    having traveled through said communication channel;
    -   correlating said receive signal s'(t) with said
    first pseudo noise signal PN(t) to generate a
    recovered carrier signal f'(t); and
    -   determining characteristics of components of the
    communication channel on the basis of a comparison of
    said clean carrier signal f(t) and said recovered
    carrier signal f'(t).

2. Method according to claim 1, wherein the level of said
    PN modulated clean carrier signal s(t) is at least 15
    dB below the level of said payload signal.

3. Method according to claim 2, wherein the level of said
    PN modulated clean carrier signal s(t) is at least 25
    dB below the level of said payload signal.

4. Method according to any one of claims 1 to 3, wherein
    said first pseudo noise signal PN(t) is a binary
    pseudo noise sequence.

5. Method according to claim 4, wherein said binary pseudo noise sequence is generated by means of a feed back shift register or a memory device in which a sequence of values of a pseudo noise signal is stored.

6. Method according to any one of claims 1 to 5, wherein a chiprate of said first pseudo noise signal PN(t) is less than 5 MChip/s.

7. Method according to claim 6, wherein a chiprate of said first pseudo noise signal PN(t) is less than or equal to 2,5 MChip/s.

8. Method according to any one of claims 1 to 7, wherein said correlating of said receive signal s'(t) and said first pseudo noise signal PN(t) is achieved by delaying said first pseudo noise signal PN(t) and multiplying the delayed first pseudo noise signal PN(t) and said receive signal s'(t).

9. Method according to any one of claims 1 to 8, further comprising:
    -   generating a second pseudo noise signal $PN_R(t)$;
    -   modulating a reference carrier signal $f_R(t)$ with said second pseudo noise signal $PN_R(t)$ to generate a PN modulated reference carrier signal $s_R(t)$;
    -   transmitting said PN modulated reference carrier signal $s_R(t)$ simultaneously with said payload signal through said communication channel at a level below the level of said payload signal;
    -   receiving a reference receive signal $s_R'(t)$ corresponding to said PN modulated reference carrier signal $s_R(t)$ after having traveled through said communication channel;
    -   correlating said reference receive signal $s_R'(t)$ with said second pseudo noise signal $PN_R(t)$ to

generate a recovered reference carrier signal $f_R'(t)$; and

— determining characteristics of components of the communication channel also on the basis of a comparison of said reference carrier signal $f_R(t)$ and said recovered carrier signal $f_R'(t)$.

10. Method according to claim 9, wherein the level of said PN modulated reference carrier signal $s_R(t)$ is at least 15 dB below the level of said payload signal.

11. Method according to claim 10, wherein the level of said PN modulated reference carrier signal $s_R(t)$ is at least 25 dB below the level of said payload signal.

12. Method according to any one of claims 9 to 11, wherein said second pseudo noise signal $PN(t)$ is a binary pseudo noise sequence.

13. Method according to claim 12, wherein said binary pseudo noise sequence is generated by means of a feed back shift register or a memory device in which a sequence of values of a pseudo noise signal is stored.

14. Method according to any one of claims 9 to 13, wherein said correlating of said reference receive signal $s_R'(t)$ and said second pseudo noise signal $PN_R(t)$ is achieved by delaying said second pseudo noise signal $PN_R(t)$ and multiplying the delayed second pseudo noise signal $PN_R(t)$ and said reference receive signal $s_R'(t)$.

15. Method according to any one of claims 1 to 14, wherein said communication channel is a transponder of a communication satellite.

16. Method according to claims 14 and 15, wherein said PN modulated reference signal $s_R(t)$ is transmitted through the same transponder of the satellite and said second pseudo noise signal $PN_R(t)$ not correlated with said pseudo noise signal $PN(t)$.

17. Method according to claims 14 and 15, wherein said PN modulated reference signal $s_R(t)$ is transmitted through a different transponder of the satellite.

18. Method according to any one of claims 1 to 17, wherein one of the characteristics of said communication channel is group delay and / or amplitude response.

19. Apparatus for determining characteristics of components of a communication channel through which a payload signal is transmitted at a predetermined level, comprising:

   - first pseudo noise signal generating means (9) for generating a pseudo noise signal $PN(t)$;

   - first modulating means (10) for modulating a clean carrier signal $f(t)$ with said first pseudo noise signal $PN(t)$ to generate a PN modulated clean carrier signal $s(t)$;

   - transmitting means (11, 12, 13) for transmitting said PN modulated clean carrier signal $s(t)$ simultaneously with said payload signal through said communication channel at a level below the level of said payload signal;

   - receiving means (13, 14) for receiving a receive signal $s'(t)$ corresponding to said PN modulated clean carrier signal $s(t)$ after having traveled through said communication channel; and

   - first correlating means (14) for correlating said receive signal $s'(t)$ with said pseudo noise signal $PN(t)$ to generate a recovered carrier signal $f'(t)$.

20. Apparatus according to claim 19, wherein the level of said PN modulated clean carrier signal s(t) is at least 15 dB below the level of said payload signal.

5 21. Apparatus according to claim 20, wherein the level of said PN modulated clean carrier signal s(t) is at least 25 dB below the level of said payload signal.

22. Apparatus according to any one of claims 19 to 21,
10 wherein said first pseudo noise signal generating means (9) is a feed back shift register or a memory device in which a sequence of values of a pseudo noise signal is stored.

15 23. Apparatus according to any one of claims 19 to 22, wherein a chiprate of said first pseudo noise signal PN(t) is less than 5 MChip/s.

24. Apparatus according to claim 23, wherein a chiprate of
20 said first pseudo noise signal PN(t) is less than or equal to 2,5 MChip/s.

25. Apparatus according to any one of claims 19 to 24, further comprising first delaying means (16) for
25 delaying said first pseudo noise signal PN(t).

26. Apparatus according to any one of claims 19 to 25, further comprising
    -    second pseudo noise generating means (17) for
30 generating a second pseudo noise signal $PN_R(t)$;
    -    second modulating means (18) for modulating a reference carrier signal $f_R(t)$ with said second pseudo noise signal $PN_R(t)$ to generate a PN modulated reference carrier signal $s_R(t)$;
35   -   transmitting means (11, 12, 13) for transmitting said PN modulated reference carrier signal $s_R(t)$ simultaneously with said payload signal through said

communication channel at a level below the level of said payload signal;

- receiving means (13, 14) for receiving a reference receive signal $s_R'(t)$ corresponding to said PN modulated reference carrier signal $s_R(t)$ after having traveled through said communication channel; and

- second correlating means (20) for correlating said reference receive signal $s_R'(t)$ with said second pseudo noise signal $PN_R(t)$ to generate a recovered reference carrier signal $f_R'(t)$.

27. Apparatus according to claim 26, wherein the level of said PN modulated reference carrier signal $s(t)$ is at least 15 dB below the level of said payload signal.

28. Apparatus according to claim 27, wherein the level of said PN modulated reference carrier signal $s(t)$ is at least 25 dB below the level of said payload signal.

29. Apparatus according to any one of claims 26 to 28, wherein said second pseudo noise signal generating means (9) is a feed back shift register or a memory device in which a sequence of values of a pseudo noise signal is stored.

30. Apparatus according to any one of claims 29 to 34, further comprising second delaying means (19) for delaying said second pseudo noise signal $PN_R(t)$.

31. Apparatus according to any one of claims 19 to 30, wherein one of the characteristics of said communication channel is group delay and / or amplitude response.

Fig. 1

2 / 4

from satellite

to satellite

Fig. 2

Antenna ── 13

High Power Amplifier ── 12

Upconverter ── 11

Downconverter ── 14

s'(t)

s(t)

10

f(t)

15

PN(t+Δt)

16

f'(t)

PN(t)

Pseudo Noise Generator ── 9
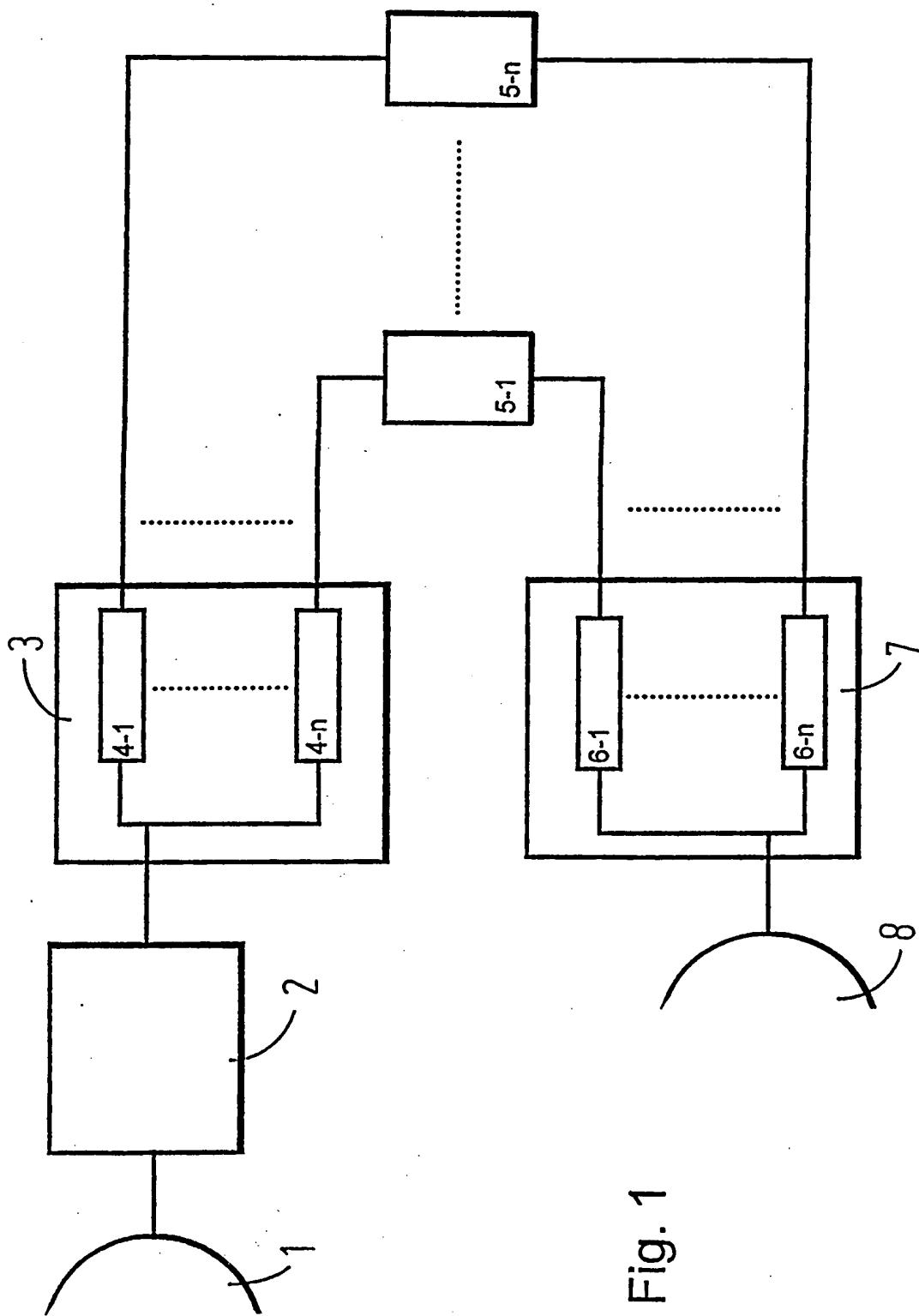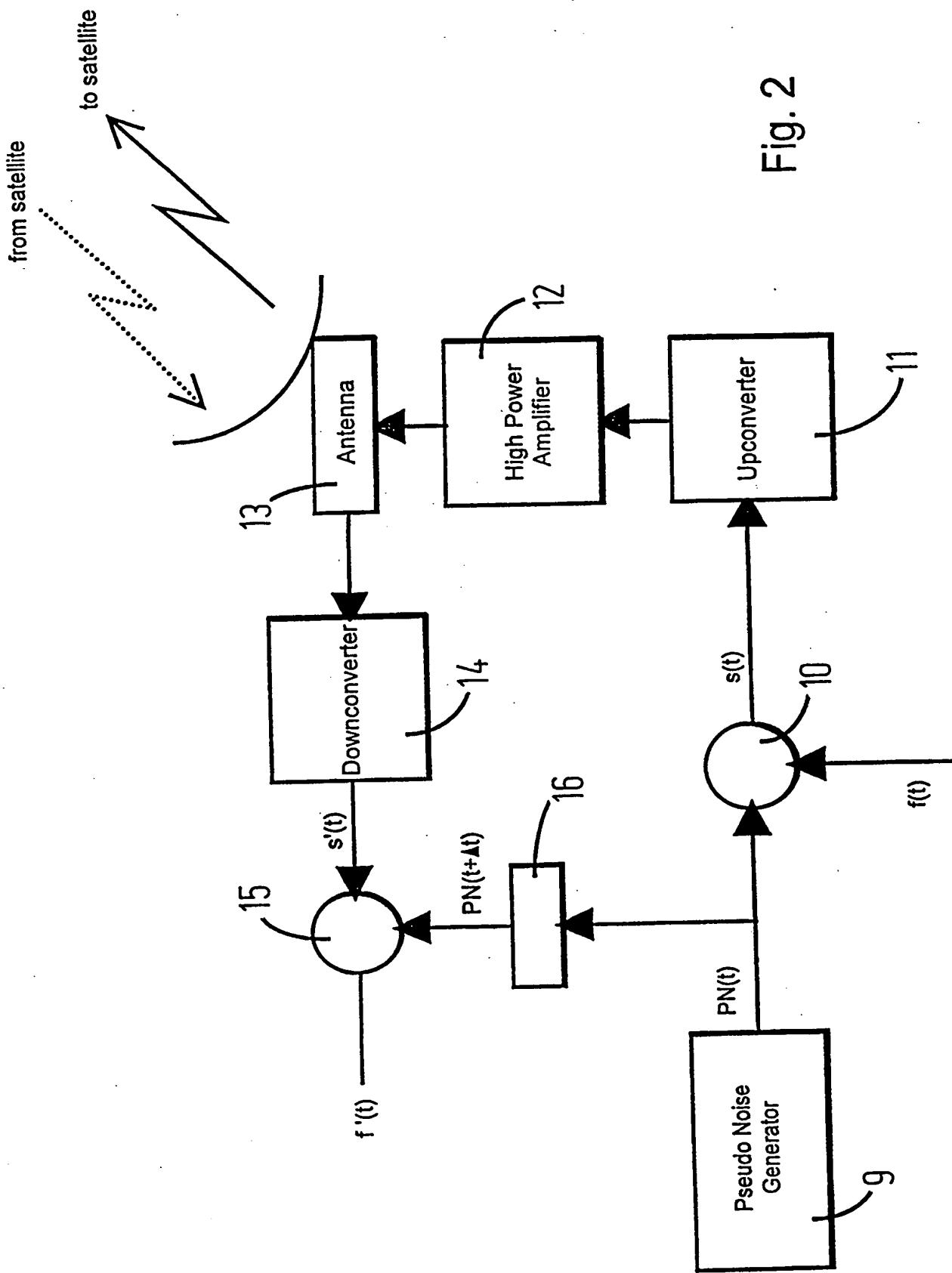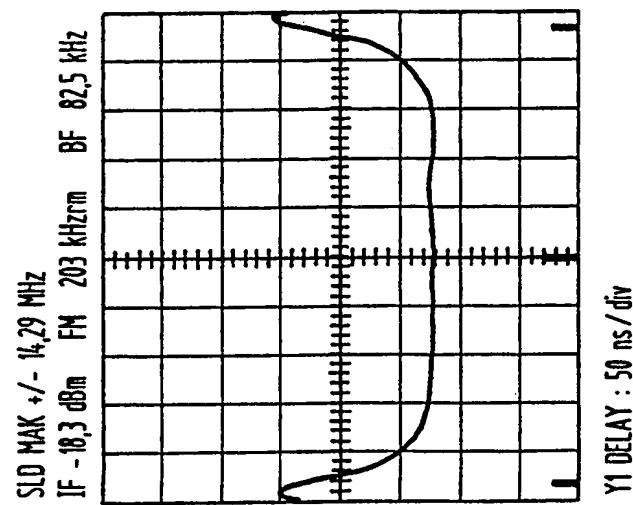
Fig. 3b
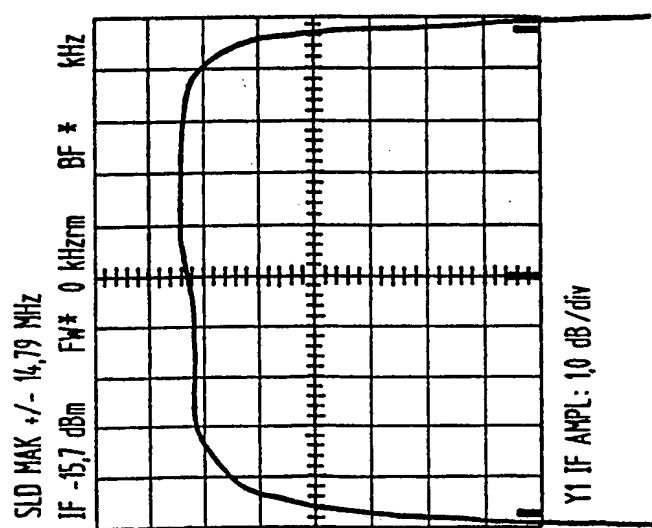
Fig. 3a

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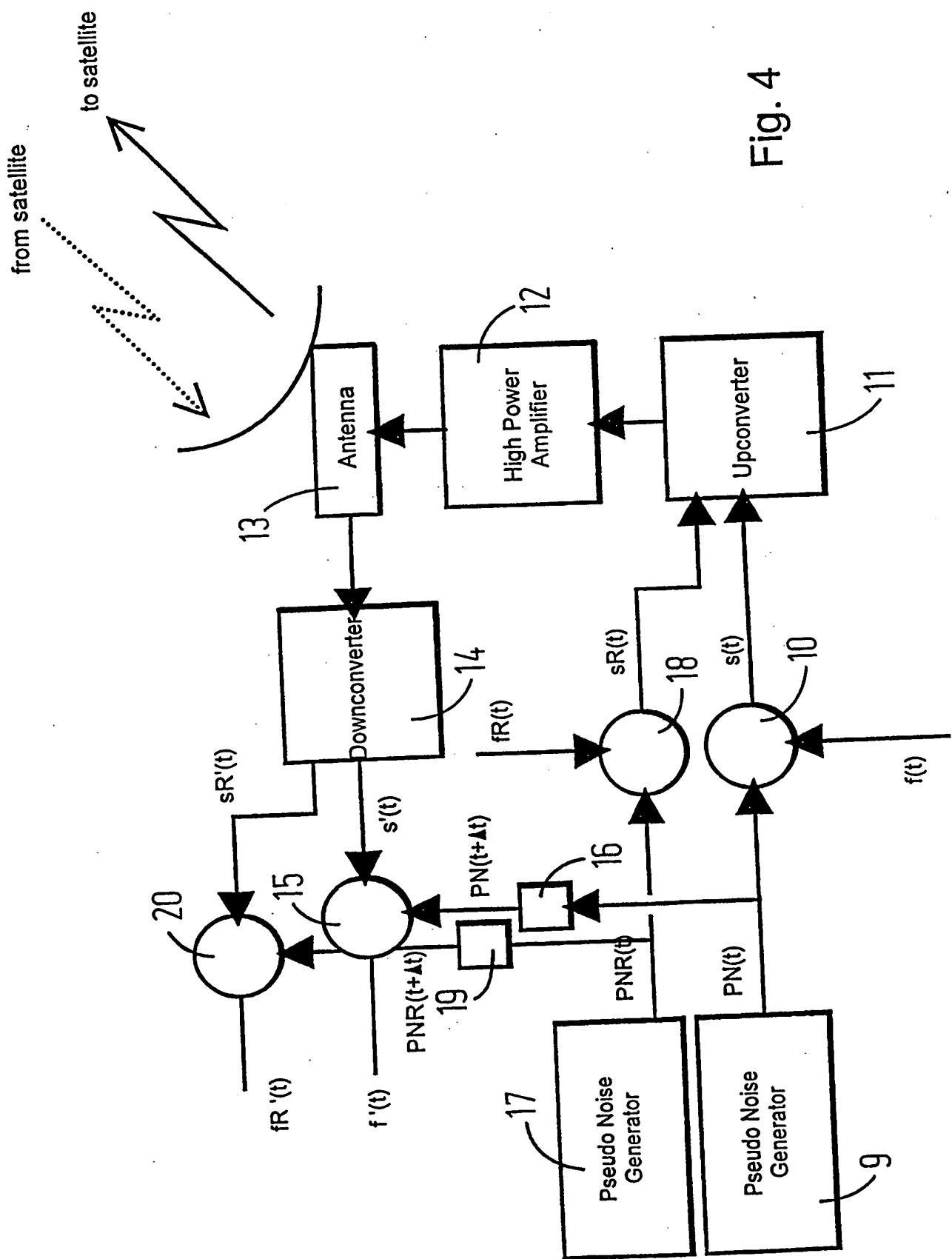
Fig. 4

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6   H04B17/00   H04B7/185

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6   H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 637 017 A (ASSAL FRANCOIS T ET AL) 13 January 1987 see abstract; claim 1	1,19
A	DE 36 44 175 A (MESSERSCHMITT BOELKOW BLOHM) 14 July 1988 see the whole document	1,19
A	EP 0 420 230 A (HUGHES AIRCRAFT CO) 3 April 1991 see abstract; claim 1; figure 1	1,19
A	US 5 036 523 A (BRISKMAN ROBERT D) 30 July 1991 see abstract; claim 1	1,19

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 April 1999	26/04/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Kolbe, W

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
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			JP 7056974	B	14-06-1995
US 5036523	A	30-07-1991	AU 6879191	A	28-04-1991
			WO 9105420	A	18-04-1991

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